

## THE CHROMOSOMES OF THE DOMESTIC TURKEY

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In a previous article (Biological Bulletin, Vol. LII, No. 5, May, 1927), I have described the chromosomes of the Indian runner duck, giving the probable number and forms, and have proposed a scheme for sex-linkage and sex-determination. The present study was undertaken in 1927 to find out whether or not the conditions found in the duck exist in other avian forms.

This study is based on the examination of approximately 800 mitotic figures taken from 35 individuals. The same four general methods of technique were employed as in the former work, except that in the technique for sectioned material of the testis, Bergamot oil was used instead of cedar oil. Since the tissues of the turkey were more difficult to prepare than those of the duck, the utmost precision was necessary in order to obtain desired results.

As in the duck, the cells of the male contain an even number of chromosomes, and the cells of the female an odd number and one more than is found in the cells of the male. The number of chromosomes in the turkey appears to be the same as in the duck.

In the embryonic tissues of the male one cell was found which appeared to have 66 chromosomes (Fig. 2), but a large majority of the cells examined contained 76 chromosomes. In the embryonic tissues of the female two cells were found which contained 55 chromosomes each. One of these is shown in Fig. 7. The remainder of the female cells examined appeared to contain 77 chromosomes each. It would appear that the typical somatic numbers are 76 for the male and 77 for the female.

As in the duck the chromosomes are of three forms: J-shaped, rod-shaped, and globe-shaped, and as in the duck the chromosomes fall into three general groups. In the male of the turkey these groups consist of 6 pairs of large chromosomes, 3 pairs of short rod-shaped chromosomes, and 29 pairs of globe-shaped chromosomes. In the female there are 6 pairs of large chromosomes, resembling in size and form those of the male, plus one odd chromosome which is the largest in the group; 3 pairs of short rod-shaped chromosomes; and 29 pairs of globe-shaped chromosomes. It is apparent that the difference in the chromosomal

grouping in the duck and in the turkey is in the second and in the third groups. In the duck the second group contains nine pairs of short rod-shaped chromosomes and the third group contains 23 pairs of globe-shaped chromosomes.

In the aberrant cells of the male which contain less than 77 chromosomes (Fig. 2) all of the twelve large chromosomes of the first group are present, also the six short rod-shaped chromosomes of the second group. The missing chromosomes are the ten smallest of the third group. The same thing seems to be true in the aberrant cells of the female of less than 77 chromosomes. In these are present the 13 large chromosomes of the first group, the six rod-shaped chromosomes of the second group; but 22 of the smallest chromosomes of the third group are not present.

The same plicancy is noted in the chromosomes of the turkey as was evinced in the chromosomes of the duck. Because of this the chromo-

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#### EXPLANATION OF PLATES

All figures from the turkey are reproduced at the same scale. The drawings were outlined with an Abbe camera lucida at a magnification of 3,500 diameters, obtained with a Spencer 1/12 homogeneous immersion objective and Spencer 15X compensating ocular with draw tube set at 150 mm., and drawing made at the level of the base of the microscope. The drawings were then enlarged by means of a copying camera lucida to 7,350 diameters. Having been reduced one-third in the reproduction they now appear at a magnification of 2,450 diameters.

*W*, the large sex-chromosome carrying female-tendency genes only.

*w*, the smaller sex-chromosome which also carries female-tendency genes only.

*Z*, sex-chromosome carrying a preponderance of male-tendency genes and also sex-linked genes.

38*Z*, same as *Z*.

38*w*, same as *w*.

37 to 1, autosomes.

#### EXPLANATION OF PLATE I

FIGS. 1-4. Cells from the amnion of males of the domestic turkey. The sex-chromosome is numbered 38*Z*. Autosomes from 37 to 33 are paired according to their size.

FIG. 1. Early prophase. The large chromosomes have not yet taken the characteristic peripheral position. Seventy-six chromosomes present.

FIG. 2. A soma cell aberrant in chromosomal number. This cell has the 12 large chromosomes of the first group, the 6 rod-shaped chromosomes of the second group, and 48 chromosomes of the third group. Ten of the smallest chromosomes of the third group are missing.

FIG. 3. Early metaphase showing gonomeric grouping of the largest chromosomes. Seventy-six chromosomes present.

FIG. 4. Early metaphase showing gonomeric grouping of the largest chromosomes, also some filamentous linkage between the members of the third group. Autosomes from 37 to 33 numbered. Seventy-six chromosomes present.

FIGS. 5 and 6. First spermatocytes from smear preparations. These cells are in the prophase stage. The *Z* chromosome bivalent in each cell is numbered 38*Z*, the autosomal bivalents from 37 to 1 according to their size. Thirty-eight chromosomes present.

PLATE I



Fig. 1



Fig. 2

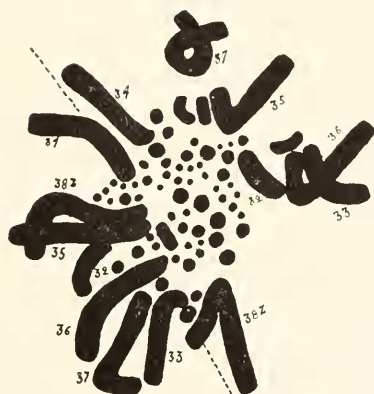


Fig. 3

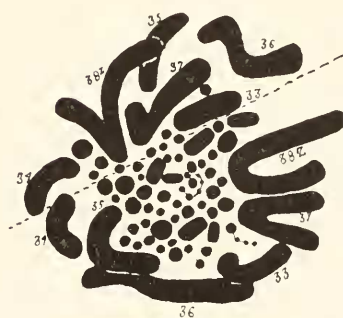


Fig. 4

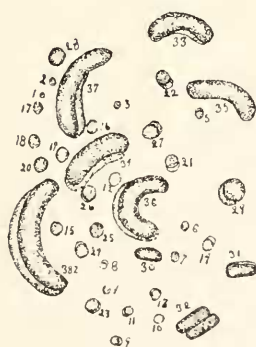


Fig. 5

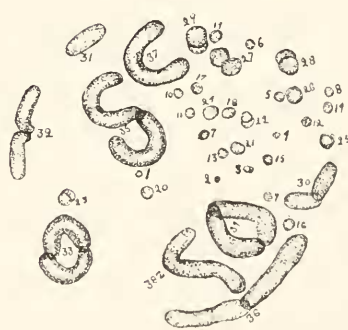


Fig. 6

somes are often found in more or less modified forms at the beginning of mitosis.

The seventy-six chromosomes in the complex of the soma cells of the male (Figs. 1, 3, 4) appear to form a graduated series from the largest of the first group, 38Z, to the smallest of the third group. Of the twelve large chromosomes which form the first group numbers 38Z, 37 and 36 appear in most cases as J-shaped and 35, 34 and 33 as rod-shaped. The six chromosomes which form the second group are all of the rod type. They are in most cases sufficiently smaller than the smallest of the first group so as not to be easily confused with them, but the slight difference in the length of the individual members of the three pairs makes it sometimes difficult to distinguish one from the other. The third group, the globe-shaped chromosomes, range in size from those containing approximately as much chromatin as the smallest of the second group to very small ones. Many of these small chromosomes are so nearly of the same size that they can be compared with no degree of certainty. Figures 5 and 6 are first spermatocytes from smear preparations of testis material. The tetrad form of many of the chromosomes is plainly apparent. It would appear that gonial mates have the same spindle attachment and that they are of the same size. In these cells the haploid number is present and the grouping of the chromosomes and the size relations are the same as in the diploid number. The germ cells are so small that in sectioned material it is practically impossible to be sure of the small chromosomes; but in most cases the large chromosomes are easily made out as to number and form. However, the testis material lends itself well to smear preparations and when the cells are well pressed out, the chromosomes are sufficiently large and clear to distinguish their number and form.

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#### EXPLANATION OF PLATE II

FIGS. 7 TO 12. Cells from the amnion of females of the domestic turkey. *H'* and 38*w* are the chromosomes that carry female-tendency factors only. Autosomes paired from 37 to 33.

FIG. 7. A prophase aberrant in chromosomal number. There are present the thirteen large chromosomes of the first group, the six rod-shaped chromosomes of the second group, and thirty-six of the chromosomes of the third group. Twenty-two of the smallest chromosomes of the third group are missing. Fifty-five chromosomes present.

FIG. 8. Prophase. Seventy-seven chromosomes present. Some filamentous linkage shown. Seventy-seven chromosomes present.

FIGS. 9 TO 12. Cells in metaphase. The stippled line in each case shows a possible gonomeric grouping. This grouping in each case has been considered with especial reference to the twelve largest chromosomes. Filamentous linkage of chromosomes shown in each cell. Autosomes paired from 37 to 33. Seventy-seven chromosomes present.

PLATE II



Fig. 7



Fig. 8

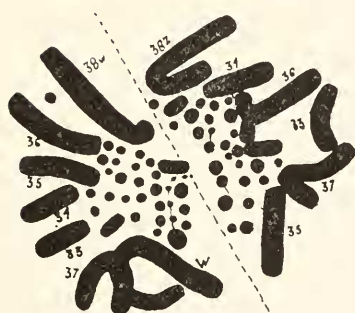


Fig. 9

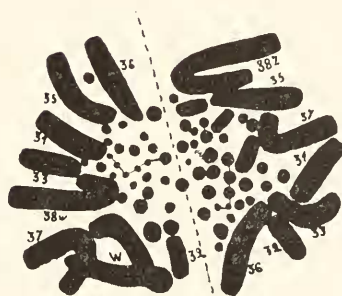


Fig. 10



Fig. 11

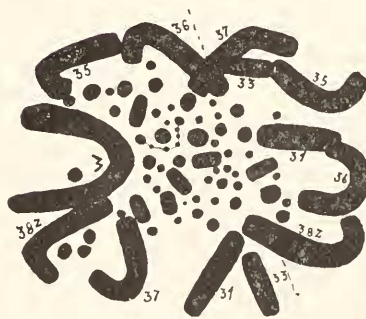


Fig. 12

As in the duck there is one more chromosome in the complex of the female than in the male. There are probably seventy-seven (Figs. 8-12). The odd chromosome is the largest in the complex. In these figures it is designated as *H'*. This large chromosome, which is evidently a sex-chromosome, is quite pliant and apparently adjusts itself to other chromosomal regions and to the nuclear wall. For some time this chromosome was regarded as rod-shaped, but in anaphase it is J-shaped. However, it differs from the other J-shaped chromosomes in the complex in that the end that forms the loop of the *J* is tapering whereas the other J-shaped chromosomes are approximately uniform in diameter throughout their entire length. The next two largest chromosomes (38 $\alpha$ -38 $Z$ ) are apparently J-shaped. As in the duck it is difficult to say whether or not they are gonial mates. If the theory advanced in the former study concerning sex determination is correct then they are not gonial mates, but one of them must be regarded as a homologue of the 38's in the cells of the male and the other as a  $\pi$  chromosome. The remaining chromosomes in the complex of the female appear approximately the same as those of the same numbers in the cells of the male.

As in the duck gonomeric grouping is evident. In the metaphase of males (Figs. 3, 4) and in the metaphase of females (Figs. 9-12). As in the duck "... in the cells of the male the largest chromosomes are grouped six on one side of the forming equatorial plate and six on the other. ... In the cells of the female there are six on one side of the plate and seven on the other. ... In every case there is in the group of seven, one chromosome which is larger than the others which has the characteristic form of the largest odd chromosome in the cells of the female, large at one end and taper at the other." (Werner, Biological Bulletin, Vol. LII, No. 5, May, 1927).

I have not been able to determine whether the two halves of a nucleus are of exactly the same size. It would appear that in some cases there is some discrepancy in this respect. Neither have I been able to determine whether or not homologous chromosomes are of exactly the same size in any one stage of mitosis. In pairing the chromosomes I have selected as homologues those that are more nearly of the same shape and length. It is possible that there is a difference in the amount of chromatin material in some or all of the homologues. The chromosomes of the male may contain more than those of the female or vice versa. This is a difficult question but one that should be investigated.

As in the duck filamentous linkage occurs in the somatic cells. In most cases observed the linkage is between members of the third group, the globe-shaped chromosomes. (Figs. 1, 4, 8, 9, 10, 11, 12.) In

other cases it was between members of the second group and some one member of the third group. (Figs. 1, 11). The numbers of chromosomes thus attached in linear arrangement range from two to seven. The filaments are in most cases one in number, although there are sometimes two. (Fig. 1). They are in all cases oxyphylic in character and are somewhat roughened or crinkly.

#### DISCUSSION

The similarities between the chromosomal complexes of the duck and of the turkey are at once apparent. In each form there is in the male an even number of chromosomes, while in the female there is an odd number of chromosomes and one more than is present in the cells of the male. The same condition is found in the chicken (now being investigated). As in the duck it seems probable that the largest pair of chromosomes in the male complex are the *Z* or the sex-chromosomes. Since the large *W* chromosome has been found in the female of the three forms of the aves, it seems impossible to regard it as a planosome, or supernumerary. It must, then, be regarded as an odd chromosome and if such, it is reasonable to suppose that it is a sex-chromosome. Since it is found only in the cells of the female, it is evident that it is concerned only with femaleness. It is equally evident that it does not carry sex-linked characters but that this must be the function of some other chromosome in the female complex. The scheme proposed in the former article for sex-linkage and sex-determination in the duck is entirely applicable in the case of the turkey and it seems unnecessary to repeat it in detail in this article. The generalities are that the female tendencies are carried by the *Ww* chromosomes, the male by the *Z* chromosomes. In both sexes the sex-linked tendencies are carried by the *Z* chromosomes. The autosomes are in a balanced condition between maleness and femaleness. It follows that a zygote receiving a genic complex equally balanced between maleness and femaleness, plus that which contains genes for maleness only (the *Z* chromosome of the male) would of necessity become a male. A zygote receiving a genic complex equally balanced between maleness and femaleness plus the *Z* chromosome, which contains genes for maleness only, and in addition the *Ww* chromosomes which carry genes for femaleness only, would become a female. It would, of course, follow that the  $F_1$  and  $F_2$  generations would inherit as is usual in such sex-linkage and as has been outlined in the previous article.

## SUMMARY

1. The chromosomes in the somatic cells of the turkey agree in number with the chromosomes in the somatic cells of the duck. These "appear to be 76 chromosomes for the male and 77 chromosomes for the female. There is present in the cells of the female a long unpaired chromosome which is not found in the cells of the male. There is reason to suppose that there are probably among the remaining six largest chromosomes two more unpaired chromosomes, one of which, the largest, is probably homologous to the largest pair (sex-linkage) of chromosomes in the male complex, while the other, it is thought may be some one of the five remaining long chromosomes." (Werner.)

2. As in the duck the 76 chromosomes appear to fall into three general groups. In the duck these groups consist of six pairs of large chromosomes, including three J-shaped and three rod-shaped; nine pairs of short rod-shaped chromosomes; and twenty-three pairs of globe-shaped chromosomes. In the turkey the first group consists of six pairs of large chromosomes, including four pairs of J-shape and two pairs of rod-shape. The second group consists of three pairs of short rod-shaped chromosomes; the third group consists of 29 pairs of globe-shaped chromosomes, which as in the duck, form a closely graduated series.

3. As in the duck there appear to be 38 bivalents in the primary spermatocytes of the male. These agree with the somatic cells in size gradations.

4. Gonomeric grouping occurs in the annion cells as it does in the duck.

5. Filamentous linkage occurs in certain stages of the prophase and metaphase. This also agrees with the condition found in the duck.

6. The sex-mechanism appears to be of the  $W^{\alpha}Z-ZZ$  type similar to that found in the duck and in the moth *Phragmatobia*.

I desire to record my indebtedness to Dr. W. R. B. Robertson for the material for this work and for his criticism of the major part of the work; to the Bausch and Lomb Optical Company for the use of microscopic equipment during the year 1929; to Dr. Mary Rose Prosser, President of Cottey College, and to Mrs. Elizabeth Ott for their influence in securing from the Spencer Lens Company the proper equipment for the completion of the work.